

Lateral Intraparietal Cortex and Reinforcement Learning  
during a Mixed-strategy Game

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**Supplemental Material**

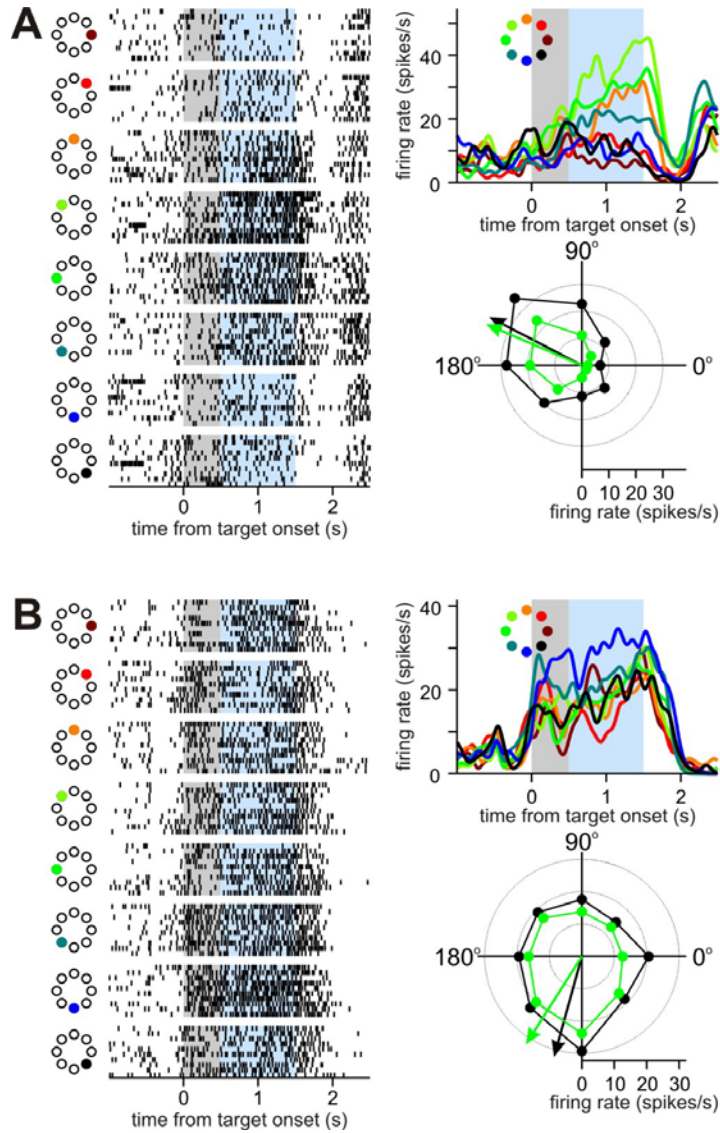
1. Directional tuning of LIP neurons

The neuron illustrated in Supplemental Figure 1A increased its activity significantly more during the delay period of the trials in which the target was presented in the leftward directions compared to the trials in which the target was presented in the rightward directions. In contrast, the neuron shown in Supplemental Figure 1B increased its activity maximally during the delay period of trials in which the animal was required to produce downward saccades. The preferred directions of these neurons with significant directional tuning tended to be contraversive to the hemisphere in which neurons were located (Supplemental Figure 2). This bias was statistically significant whether all the neurons with statistically significant tuning were considered (56 out of 85 neurons, 67.1%; binomial test,  $p < 0.05$ ), or whether only the neurons with preferred directions within  $45^\circ$  of the horizontal meridian were considered (34 out of 53 neurons, 67.9%; binomial test,  $p < 0.05$ ).

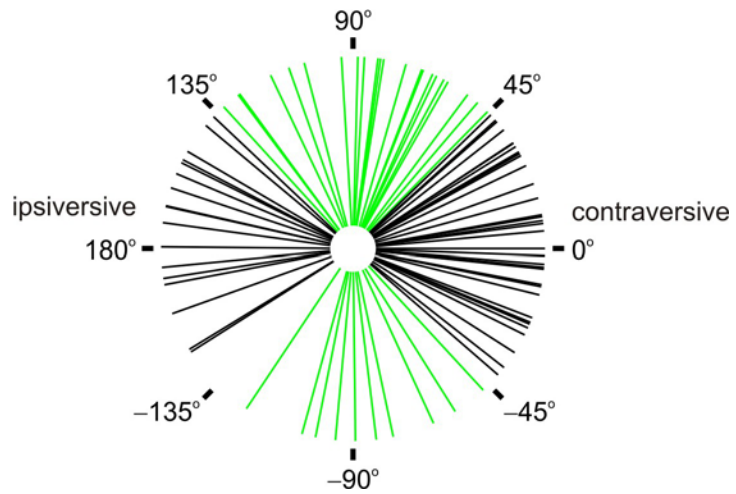
2. Effect size for the LIP signals related to choices and outcomes (Supplemental Figure 3).

3. Comparison of signals related to value functions in different cortical areas (Supplemental Figure 4).

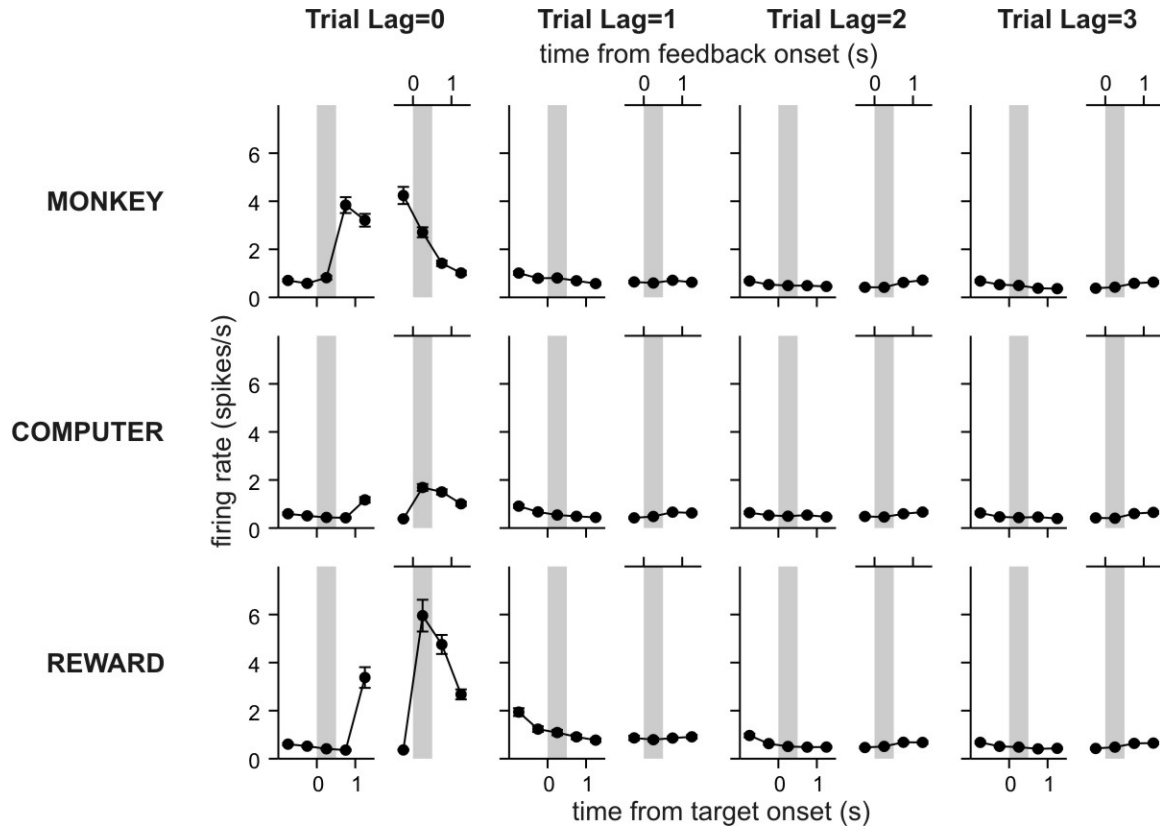
4. Comparison of signals related to choice and reward histories in different cortical areas (Supplemental Figure 5).



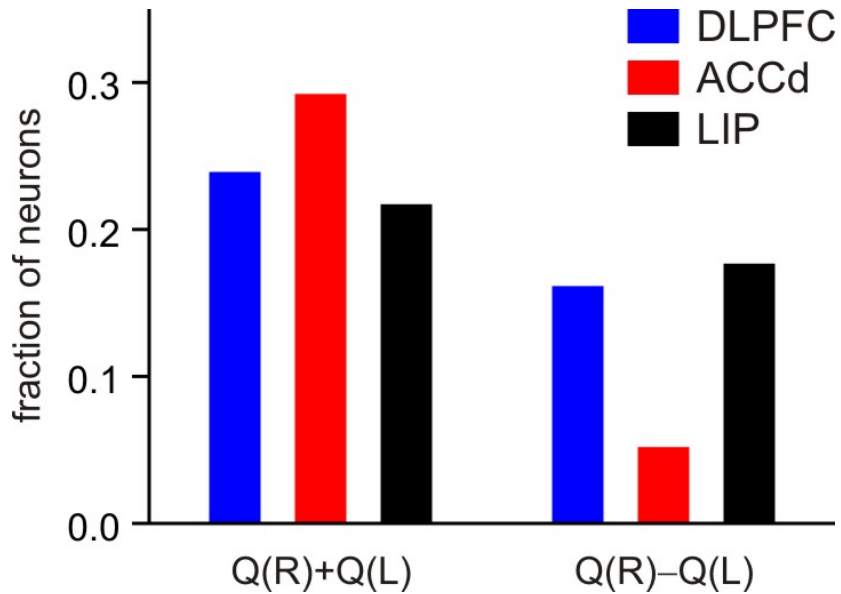
**Supplemental Figure 1.** Activity of LIP neurons during the memory saccade task. A. An LIP neuron showing the delay activity tuned along the horizontal axis. B. An LIP neuron with the delay activity tuned along the vertical axis. Left. Raster plots show the spiking activity during the memory saccade trials sorted according to the position of the saccade target as indicated by a colored dot in the iconic representation of potential target locations. Top right. Spike density functions estimated separately according to the position of the saccade target. Bottom right. Directional tuning curve showing the average activity during the delay period (black) and the following 0.5-s saccade period (green) for each target location. Gray and blue backgrounds indicate the cue and memory periods, respectively.



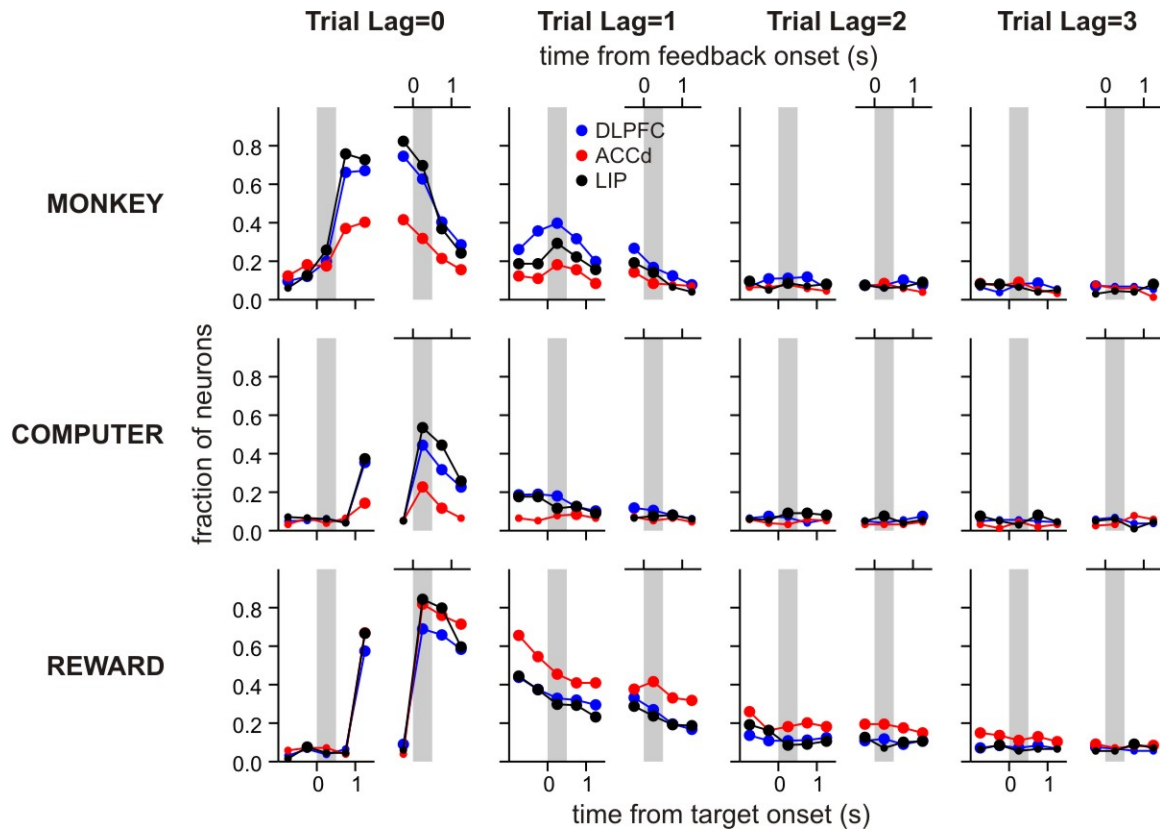
**Supplemental Figure 2.** Distribution of preferred directions for the LIP neurons that showed significant directional tuning. Green lines show the preferred directions within 45° from the vertical meridian.



**Supplemental Figure 3.** Magnitude and time course of LIP activity related to various choices and outcomes. Each symbol indicates the average magnitude of the regression coefficient associated with the animal's choice (top), the choice of the computer opponent (middle), and the animal's reward in the current (Trial Lag=0) or previous trials (Trial Lag=1 to 3). This was obtained from the regression model that did not include the value functions (Eq 9 in the text). Gray background correspond to the delay period (left panels) or feedback period (right panels).



**Supplemental Figure 4.** The proportion of neurons in the dorsolateral prefrontal cortex (DLPFC; Seo et al., 2007), dorsal anterior cingulate cortex (ACCd; Seo and Lee, 2007), and the LIP (this study) that showed significant modulations in their activity related to the sum and difference of value functions (permutation test,  $p < 0.05$ ).



**Supplemental Figure 5.** Comparison of neural activity related to choices and outcomes in the dorsolateral prefrontal cortex (DLPFC; Seo et al., 2007), dorsal anterior cingulate cortex (ACCd; Seo and Lee, 2007), and the LIP (this study). Each symbol indicates the fraction of neurons within a particular cortical area that significantly modulated their activity according to the animal's choice (top), the choice of the computer opponent (middle), and the reward in the current (Trial Lag=0) or previous trials (Trial Lag=1 to 3). Same format as in Figure 9 of the main text.